Update

NAL Proposal #523
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A Proposal To Study Multiparticle Peripheral Hadron Reactions Yielding Forward π^o and η^o Mesons

ABSTRACT

We plan to make a systematic study of multiparticle peripheral hadron reactions yielding forward-going π^o and η^o mesons. We plan to carry out these studies at several energies between 20 and 300 GeV/c. The proposal is to study these reactions by installing the CIT photon detector (used in the π^-p charge exchange experiment, E111) in the multiparticle spectrometer (currently being used for E110). Installation will be carried out parasitically with the Fall 1977 E110 data-taking run. The physics goals include a search for new particle states in the $\pi^+\pi^-\pi^o$ $\pi^+\pi^-\eta^o$, $K^o\pi^o$, $K^oK^o\pi^o$ mass spectra up to large effective masses as well as a study of the dynamics (s and t dependences) of the production of known particles (ω^o, η', etc.). The detection efficiencies and effective mass resolutions for these final states are quite good. We will collect data on these reactions by running in a multiple-trigger configuration.

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I. Physics Motivation

A. Introduction

This is a proposal to study multiparticle peripheral reactions yielding a forward-going π^o. The general class of reactions to be studied are described by the process

$$A + p \rightarrow C + D \qquad (1)$$

where

A - is an incident π, K, p or $\bar{p}$;

C - is a peripherally-produced (forward in the lab) resonance or a system of particles which decays into one, two, or three particles and a π^o (e.g., $C = \omega^o \rightarrow \pi^+\pi^-\pi^o$); and

D - is a one, two, or three particle system produced with low momentum in the lab.

The study of reaction (1) when C and D are stable particles or resonances is particularly interesting from a theoretical point of view in that we can test the various models which make predictions about the dynamics (s and t dependences) of the two-body process. An an example, the charge exchange reaction

$$\pi^- p \rightarrow \pi^o n \qquad (2)$$

is described remarkably well by a simple Regge-pole model in which the ρ trajectory is exchanged. The model describes the data over the energy range extending from 20 to 200 GeV.[1] The question as to whether other reactions can be understood in terms of simple Regge exchanges is theoretically relevant. The study of reaction (1) is also of interest at high energies in that we can examine the effective mass of a system of particles containing a π^o to search for new resonances or study those resonances which are presently ambiguous. In fact, as we shall see below, the $\pi^+\pi^-\pi^o$ system is particularly rich in resonances which are both well established (e.g., again $\omega^o \to \pi^+\pi^-\pi^o$) and ambiguous (e.g., $A_1 \to \pi^+\pi^-\pi^o$).

A subset of reactions which are of the type described by (1) is currently under study by members of Fermilab experiment E110 using the Multiparticle Spectrometer (MPS) in the M6 beamline. In that experiment the forward going system, C, is required to decay into charged particles or into a K_s^o or Λ^o which are observed in their charged particle decay modes. Thus while that experiment studies a broad class of reactions the scope of the study of (1) is greatly enhanced by including those processes in which a forward π^o is produced. We discuss this point in detail below.

We propose to carry out this experiment by using the MPS facility currently being completed and used by members of the E110-260 collaboration.[2,3] To this spectrometer we will add the CIT photon detector (hereafter referred to as the photon detector) used in the π^-p charge-exchange experiment (Fermilab experiment E111).[4] A brief discussion of the characteristics of the MPS and the photon-detector are given in Sections II and III, respectively.

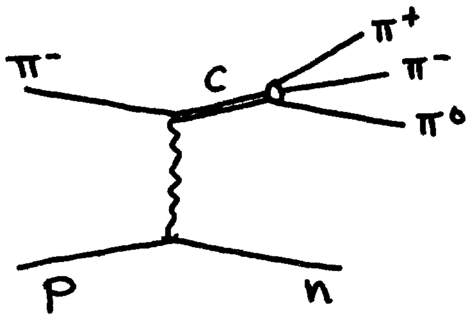
B. Production Dynamics of Known Meson Resonances

Consider the reaction

$$\begin{array}{l} \pi^- p \to C\, n \\ \qquad\quad \hookrightarrow \pi^+\pi^-\pi^o \\ \qquad\qquad\qquad \hookrightarrow \gamma\gamma \end{array} \qquad (3)$$

which is one of the reactions we plan to study and is particularly rich in physics interest as we shall see. [In this proposal our discussion will focus on π^- induced reactions. Cerenkov counters in the beam line will also allow us to distinguish K^- and $\bar{p}$ induced reactions.]

The first important feature of reaction (3) is that system C has net neutral charge. Thus, if we view the production of C in some sort of exchange picture



we see that Pomeron exchange(or to put it another way, diffraction dissociation) is ruled out. Thus, the $\pi^+\pi^-\pi^0$ is an attractive channel to search for G = -1 resonances produced with low cross sections since this channel, being neutral, is free from diffractive backgrounds which have relatively high cross sections which change slowly with energy.

The simple topology of reaction (3) readily lends itself to a simple trigger requirement which is two charged particles forward, two photons from the π^0 in the photon detector, and no slow-charged particles or π^0's produced nearly at rest. We shall consider production of resonances which decay into a $\pi^+\pi^-\pi^0$. For ready reference we list the meson resonances with this decay mode in Table I. Since the photon detector can also detect the decay η^0 through its 2γ decay mode, we also include those resonances which decay into $\pi^+\pi^-\eta^0$ and will be produced in

Table I. Meson Resonances Which Decay Into $\pi^+\pi^-\pi^o$ or $\pi^+\pi^-\eta^o$ [a]

Resonance	J^P	I^G	Partial Decay Mode	Fraction [b]	
$\eta(548)$	0^-	0^+	$\pi^+\pi^-\pi^o$	24%	
$\omega^o(783)$	1^-	0^-	$\pi^+\pi^-\pi^o$	90%	
$\eta'(958)$	0^-	0^+	$\pi^+\pi^-\eta^o$	17%	
			$\rho^o\gamma \rightarrow (\pi^+\pi^-)\gamma$	30%	
$\phi(1020)$	1^-	0^-	$\pi^+\pi^-\pi^o$	16%	
$A_1^{\,o}(1100)$	1^+	1^-	$\rho^\pm\pi^\mp \rightarrow (\pi^\pm\pi^o)\pi^\mp$	100%	
$B^o(1235)$	1^+	1^+	$\omega^o\pi^o \rightarrow (\pi^+\pi^-\pi^o)\pi^o$	90%	c
$D(1285)$	?	0^+	$\pi^+\pi^-\eta^o$	38%	
$A_2^{\,o}(1310)$	2^+	1^-	$\rho^\pm\pi^\mp \rightarrow (\pi^\pm\pi^o)\pi^\mp$	23%	
			$\eta^o\pi^o \rightarrow (\pi^+\pi^-\pi^o)\pi^o$	4%	c
			$\omega^o\pi^+\pi^- \rightarrow (\pi^o\gamma)\pi^+\pi^-$	1%	c,d
$E(1420)$	?	0^+	$K^+K^-\pi^o$	13%	c
			$\pi^+\pi^-\eta^o$	26%	
$\rho'(1600)$	1^-	1^+	$\rho^+\rho^- \rightarrow (\pi^+\pi^o)(\pi^-\pi^o)$	?	c,e
$A_3^o(1640)$	2^-	1^-	$f^o\pi^o \rightarrow (\pi^+\pi^-)\pi^o$	67%	
$\omega(1675)$	3^-	0^-	$\pi^+\pi^-\pi^o$	100%	
$K^*(890)$	1^-	$\frac{1}{2}$	$K_S^o\pi^o \rightarrow \pi^+\pi^-\pi^o$	10%	
$Q^o(1200)$	?	$\frac{1}{2}$	$K^+\pi^-\pi^o$	?	c,f
$L(1770)$	?	$\frac{1}{2}$	$K^+\pi^-\pi^o$	?	c,f

[a] From "Reviews of Particle Properties", Rev. Mod. Phys. Vol. 48, No. 2, Part II, April, 1976.

[b] These fractions take into account measured branching fractions and isospin considerations into the final state listed. When an η^o is listed as the end product of a decay we assume it is observed through its 2γ decay which 38% of all η decays.

[c] Listed since the final state is +,- neutrals.

[d] $(\omega^o \rightarrow \pi^o\gamma)/(\omega^o \rightarrow \text{all}) = 9\%$ is assumed.

[e] $\rho' \rightarrow 4\pi$ is dominant

[f] $K\pi\pi$ dominant

$$\pi^- p \rightarrow C\, n \qquad (4)$$
$$\hookrightarrow \pi^+\pi^-\eta^0$$
$$\hookrightarrow \gamma\gamma$$

1. η^0 Production

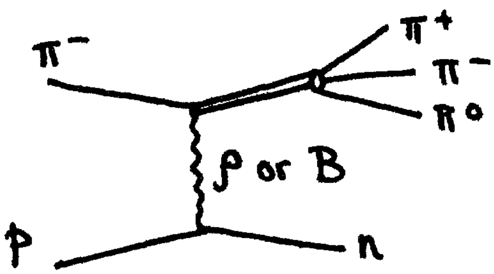
The reaction

$$\pi^- p \rightarrow \eta^0\, n \qquad (5)$$
$$\hookrightarrow \pi^+\pi^-\pi^0$$

has been studied by the E111 collaboration and has been described, in the Regge picture, by exchange of the A_2-pole.[1] Our interest in measuring (5) will mainly be to compare our data with that of E111.

2. ω^0 Production

Production of ω^0 can take place either via natural parity exchange (ρ-trajectory) or unnatural parity exchange (B-trajectory).



At lower energies (p_{LAB} = 3.7 to 5.5 GeV/c)[5] it appears that ρ- and B-exchange contributions are roughly comparable with some indication that the B-exchange contribution is falling faster with energy as one might expect. The density-matrix elements of the ω^0 measure the amount of ρ- and B-exchange.

3. η' Production

The reaction

$$\pi^- p \rightarrow \eta' n \qquad (6)$$

will be measured with η' observed via its $\eta^{o}\pi^{+}\pi^{-}$ and $\rho^{o}\gamma$ decay modes (see Table I). The study of n and η' cross sections has seen recent theoretical interest because of the sensitivity to mixing ideas and theories as to why ϕ and not η' obeys "Zweig's rule".[6]

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C. Meson Spectroscopy

Though there has been a lot of attention of late paid to charm meson searches, there are still many unsolved and important [7, 13, 14] questions for conventional charmless $q\bar{q}$ states. The current data is inadequate to test the predictions of the simple quark model let alone those of more exotic theories, e.g. the bag model[17] predicts new meson states. Tables II and III list the expected states in the two lowest lying quark multiplets — those with orbital momentum L = 0 and 1.

Table II: L = 0 Quark States

$J^{PC} = 0^{-+}$	π, K, η, η'
$J^{PC} = 1^{--}$	ρ, K^*, ω, ϕ

Table III: L = 1 Quark States

isospin \ J^P	0^+ Nonet	1^+ "B" Nonet	1^+ "A_1" Nonet	2^+ Nonet
I = 1	$\pi_N(980)$	B(1235)	A_1 (1070 - maybe higher mass[13])	$A_2(1310)$
Strange I = 1/2	κ ($\approx$1250)	$Q_1(1290)$ and $Q_2(1400)$ are mixtures of A_1 and B nonet states.		K_N^* (1420)
I = 0 singlet/octet mixing (?)	ε ($\approx$ 750)	h (?)	D (1285)	$f^0(1260)$
	S^* ($\approx$1000)	h' (?)	D' = E(1422) ?	f'(1514)

In the two 1^+ nonets, only the B(1235) is well understood and the 0^+ nonet is also in a pretty confused state[13]. As 1^+ mesons only have 3 or more particle decays, they have been hard to study in the past but our apparatus should have little trouble in triggering on and analyzing the higher multiplicity decays of interesting mesons. Important decays are

$$\begin{array}{l} K\pi\pi \\ \pi^+\pi^-\pi^\circ \\ \pi^+\pi^-\eta^\circ \\ K\bar{K}\pi \end{array} \qquad (7)$$

which we trigger on by

a) multiplicity $-K^{\pm}$, $\pi^{\pm}$

b) multiplicity change $-K^{o} \rightarrow \pi^{+}\pi^{-}$

c) photon detector $-\pi^{o}$

As discussed in our E110 update[15], we will use a semi-inclusive trigger which selects forward systems (7) through our magnet aperture and any number of particles around the target. This technique is necessary because exclusive cross-sections are almost certainly too small at high energies to allow useful studies.

Note the decay modes (7) allow one to study <u>all</u> the unknown mesons in table II (A_1, Q_1, Q_2, D, D', h, h') and also the many higher mass states expected, for instance, from L = 2 orbital excitation of quark model. One selects final states (7) that have net zero charge to avoid diffractive (and often dull) processes. Even with this restriction, (7) includes many decays (e.g., $\pi^{+}\pi^{-}\pi^{o}$, $\pi^{+}\pi^{-}\eta$) that cannot be studied without the photon detector and hence will not be looked at in E110.

The photon detector allows an energy trigger and hence a cleaner signature of the fast systems we want than is possible with the pure charged particle multiplicity trigger of E110. This may enable more sensitive studies than is possible for E110 - for instance, one may be able to go to higher multiplicity (e.g., $K^{o}\pi^{+}\pi^{-}\pi^{o}$ forward) triggers and look for resonances in 3, 4 . . . body channels.

The $K^{o}\bar{K}^{o}$ trigger in E110 is particularly nice as it is free from backgrounds of charged particles interacting near the A station.† The π^{o} detector will allow us to use this nice trigger to study $\bar{K}K^{*}$ resonances as well as the limited E110 set that decay to two pseudoscalars $K\bar{K}$. We find that $K^{o}\bar{K}^{o}$ trigger (which of course includes $K^{o}\bar{K}^{o}\pi^{o}$) rate is .73 per 10^{-6} in the

†This is the first proportional chamber station after the target used in the multiplicity trigger.

100 GeV E110 trigger studies whereas the rate for the high background $K^o\bar{K}^o\pi^-$ channel was 40 times bigger.

D. Charm Spectroscopy

This experiment will also be sensitive to charmed particles produced with $x \gtrsim 0.5$. The channel $K_s^o\pi^o$ will be studied simultaneously with the $\pi^+\pi^-\pi^o$ channel. The neutral Vee decay ($K_s^o \to \pi^+\pi^-$) topology will be used as a trigger requirement. This will allow us to search for charmed mesons. For example, we will be sensitive to the decays

$$D^o \to \bar{K}^o\pi^o, \quad \bar{K}^o \to \pi^+\pi^-$$

$$D^o \to \bar{K}^o\pi^o\pi^o, \quad \bar{K}^o \to \pi^+\pi^-$$

$$F^+ \to K^oK^{*+}, \quad K^{*+} \to K^*\pi^o, \quad K^o \to \pi^+\pi^-$$

We do not emphasize this part of the proposal as charmed particles have proven so elusive in hadron collisions. Further, one might expect dynamics to suppress the forward production studied in this experiment. However, one big advantage of our mode is the great suppression of combinatorial background compared to searches near $x = 0$. This can be illustrated by our own MPS data: In the jet triggers of E260 (mainly high multiplicity, small x) we have yet to see a ρ resonance signal. However, in half an hour's beam time of E110 we see clear ρ and f^o signals from both the diffractive ($\pi^+\pi^-\pi^-$) and two prong ($\pi^+\pi^-$) triggers.

E. Diffractive Processes Involving Peripheral Production of Meson Resonances

An example of other physics which can be studied experimentally with forward-neutral detection is the reaction:

$$\left\{\begin{matrix}\pi^-\\ K^-\end{matrix}\right. p \rightarrow \left\{\begin{matrix}\pi^-\\ K^-\end{matrix}\right. \underset{\hookrightarrow\ \pi^+\pi^-\underset{\hookrightarrow\ 2\gamma}{\pi^\circ}}{\omega^\circ} \quad p \tag{8}$$

This allows the study of the production dynamics and spectroscopy of resonances (for instance B(1235). Note also that a high mass resonance was recently found in the analogous baryon channel[16] - namely,

$$\pi^\pm p \rightarrow \pi^\pm N^{*+} \rightarrow \pi^\pm p\omega^o.$$

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II. The Multiparticle Spectrometer (MPS)

A. Overall View

The MPS is described in References 2 and 3. An overall view of the spectrometer is shown in Figure 1. A more detailed view of the upstream end of the spectrometer is shown in Figure 2.

B. A Tour of the MPS

If the reader will refer to Figure 1 we will take a quick tour of the MPS starting at the upstream end.

1. Beam

The M6 beam line will deliver positive and negative particles from 20 GeV/c to 200 GeV/c. The beam line instrumentation currently includes 4 Cerenkov counters: two threshold counters, a differential counter, and a DISC counter.

2. Target Region (refer to Figure 2)

The target region includes, in addition to a 1 foot hydrogen target,

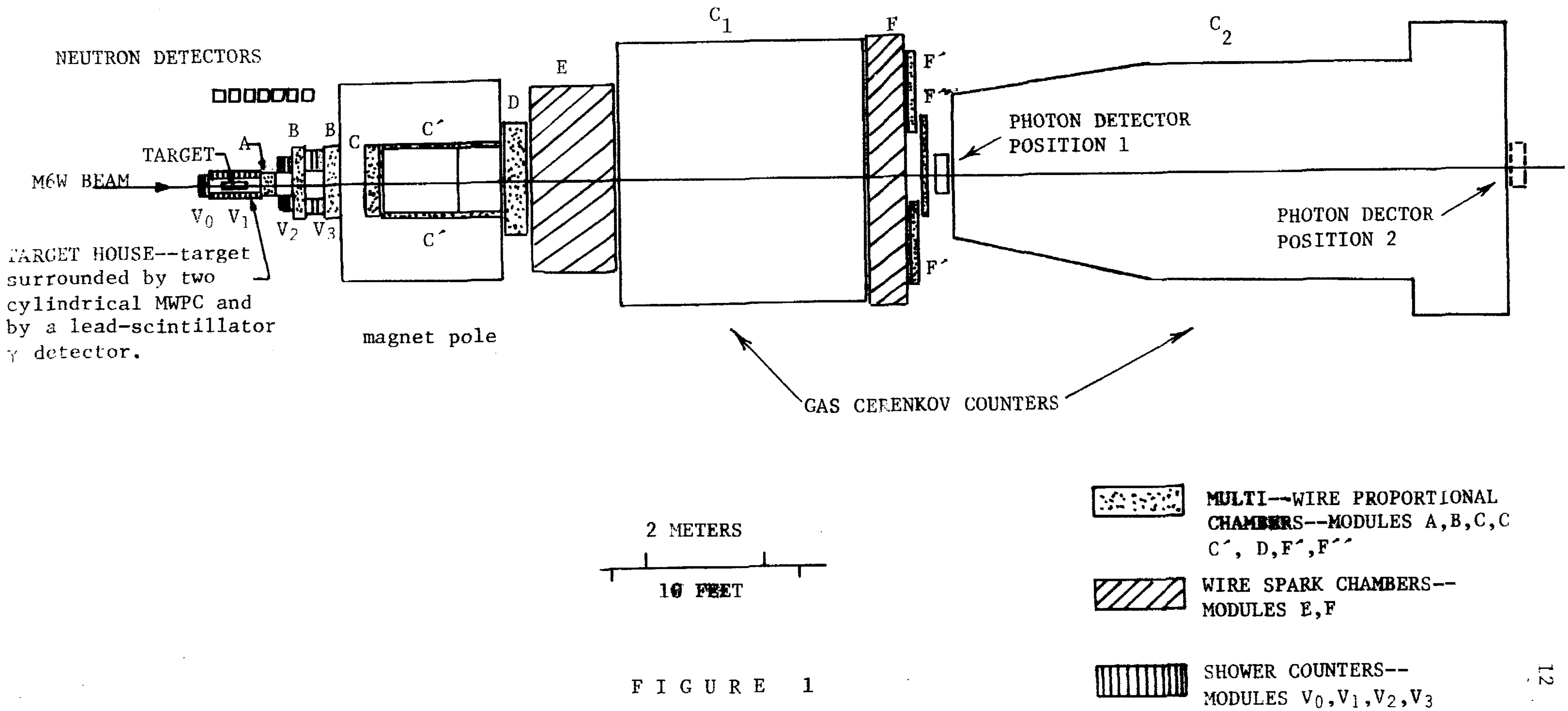
a. scintillation counters (S_A, S_B, S_C);

b. proportional wire chamber planes (1 mm spacing) just upstream and downstream of the target, (BB and A);

c. shower counters (lead-scintillator modules) V_o, V_2, and V_3 which will be used to detect the presence of slow π^o;

d. cylindrical shower counter (V_1) which is a lead scintillator array. The scintillator is segmented in strips parallel to the beam direction. These strips divide the azimuth into 24 segments which can be separately interrogated for presence of a slow π^o;

TOP VIEW - MULTIPARTICLE SPECTROMETER



F I G U R E 1

UPSTREAM VIEW OF SPECTROMETER

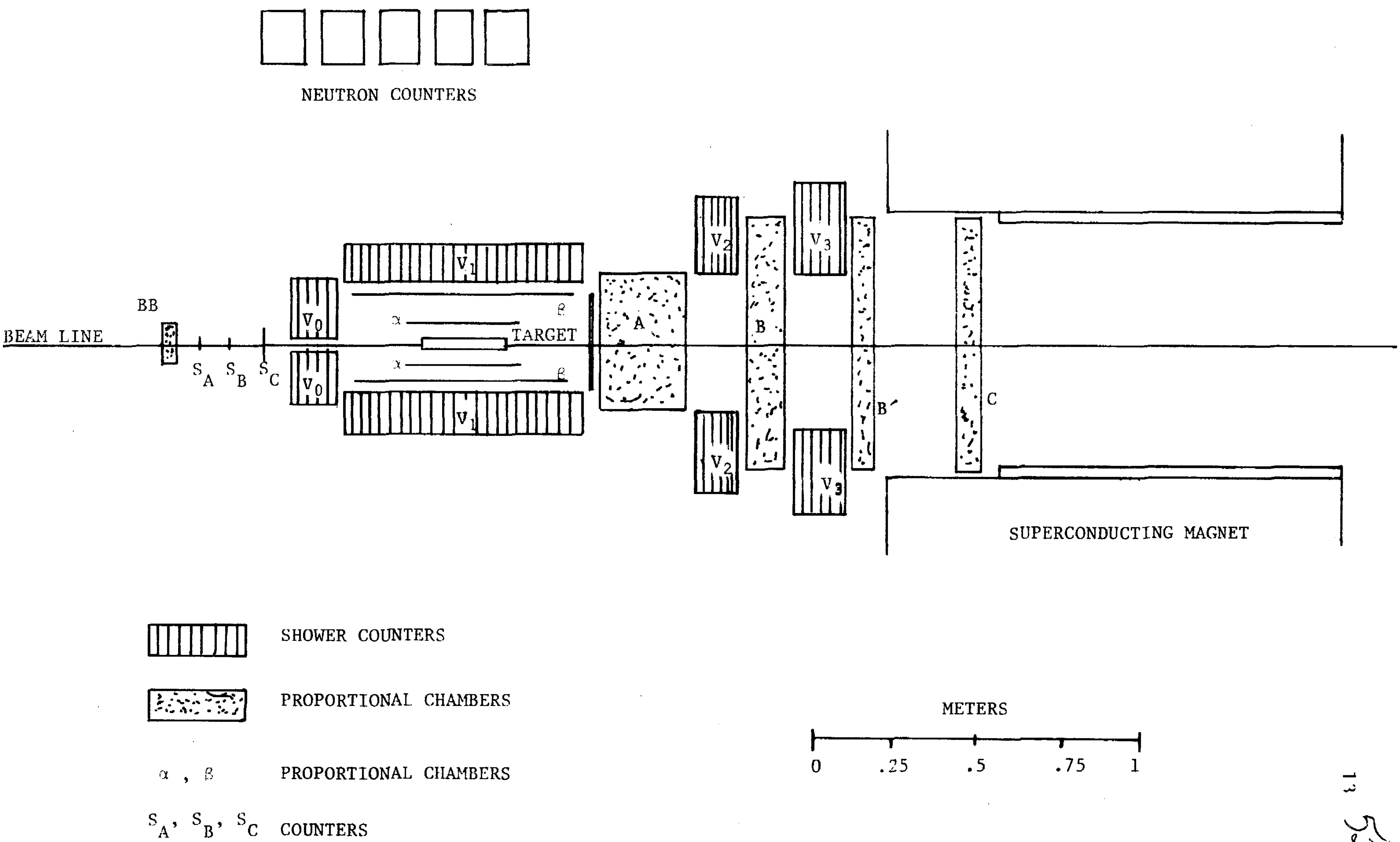


FIGURE 2

e. cylindrical proportional wire chambers (α,β) with wires parallel to the beam line. These wires divide the azimuth into 192 segments and can be used in the trigger for particle counting. The longitudinal coordinate will be read out by current-division electronics;

f. neutron counters.

3. Proportional-wire planes at Stations B, C, C' (lining magnet walls), D, F', and F". These wires are available in the trigger for making multiplicity requirements.
4. Spark chambers at Stations E and F.
5. A 2 ft. x 4 ft. x 4 ft. superconducting magnet with a $\int B \cdot dl = 18$ kg-m.
6. Atmospheric gas threshold Cerenkov counters C_1 and C_2 with segmented mirror planes (22 segments for C_1, 16 for C_2).

III. Characteristics of the Photon Detector[8]

A. Overview

The photon detector is a hodoscope shower detector which effectively samples the depth integrated transverse projection of electromagnetic showers in two orthogonal transverse dimensions. Figure 3 shows a schematic diagram of the detector. The plates are stacked normal to the direction of incident particles (z) with gaps between them of approximately 7 mm. These gaps are filled with long narrow scintillation fingers, 1.05 cm wide, which are close-packed and run the full width of the detector. Vertical and horizontal fingers are in successive gaps. The eight fingers having the same x coordinate or the same y coordinate are connected optically by curved light pipes at one end, and each set of eight fingers so connected constitutes one counter. There are 70 x-counters and 70 y-counters. Each finger has been wrapped with foil of graded reflectivity, and a light trap captures those transmitted at large angles to the finger axis. Because of this special treatment, each counter yields pulses of uniform height (within 2%) over the entire counter length.

B. Detector Resolution

The resolution of the photon detector for various processes can be calculated from the resolution for single photons. The energy resolution for single photons is understood in terms of two effects: the statistical fluctuations in the shower process and the spatial non-uniformity of the detector response. The statistical fluctuations dominate the resolution at low energies and can be represented by $\Delta E(\mathrm{rms}) \simeq \pm .18\sqrt{E}$ (E and ΔE in GeV). At high energies the spatial non-uniformity limits the energy resolution to $\Delta E(\mathrm{rms}) \simeq \pm .03\sqrt{E}$. The position resolution for single photons is $\Delta x(\mathrm{rms}) \simeq \pm 1$ mm.

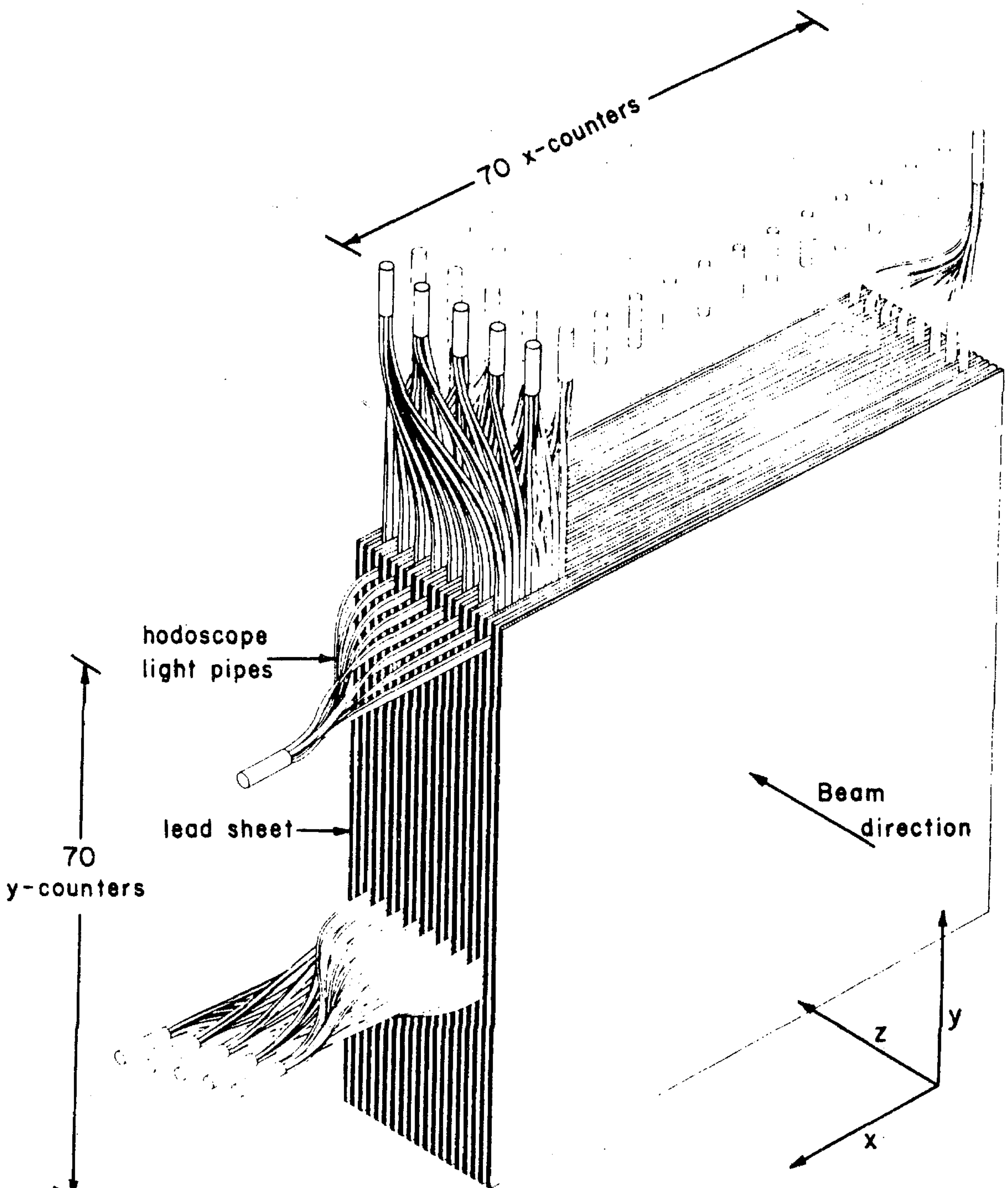
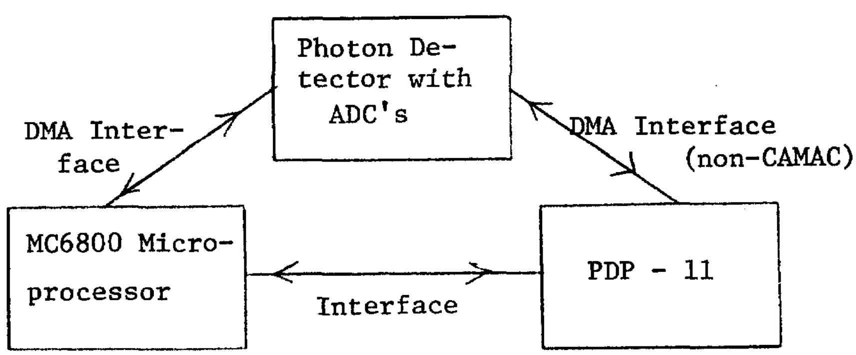


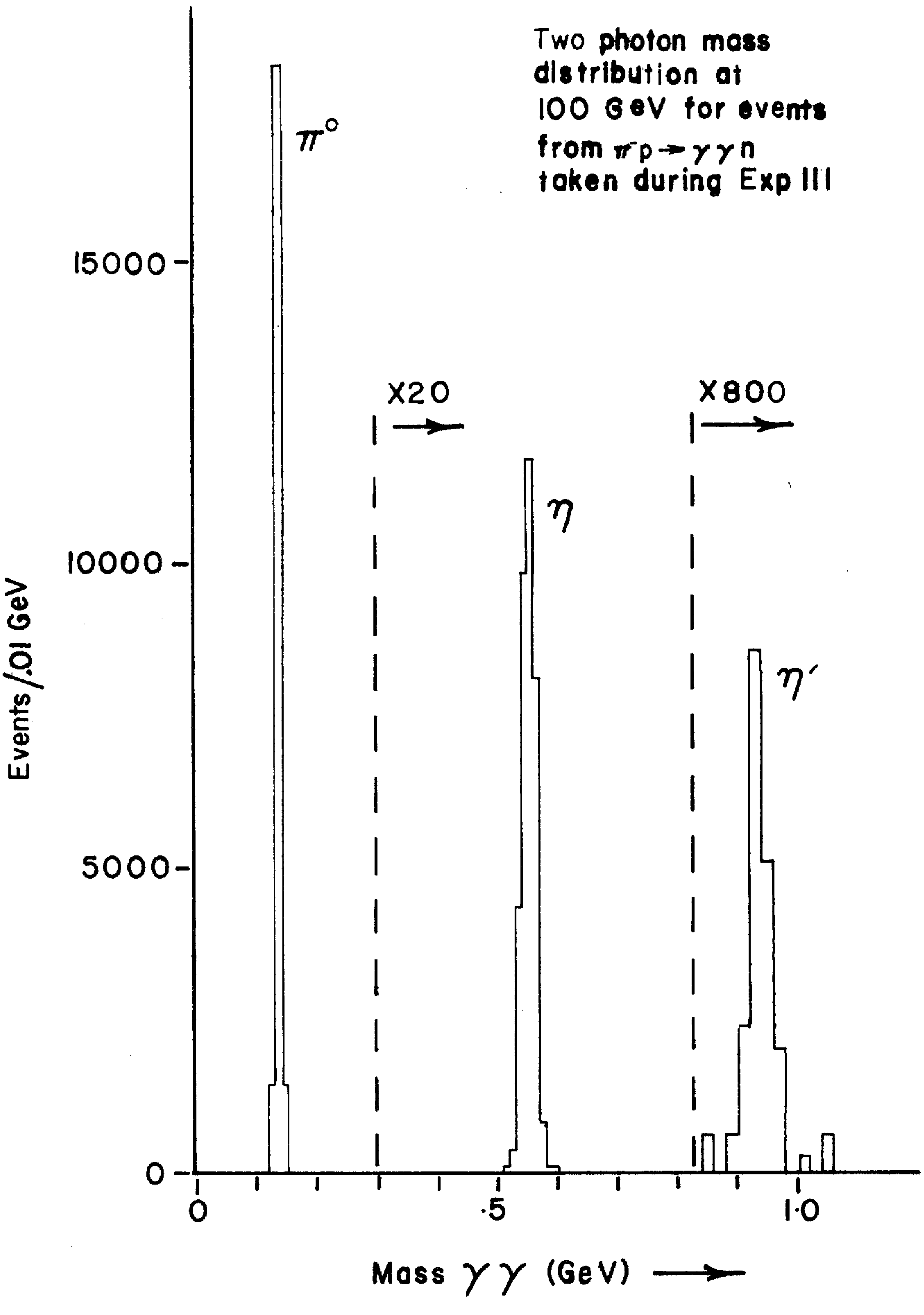
Figure 3: The Photon Detector

The resolution for multi photon states depends on the apparatus configuration and the details of the decay kinematics. A π^0 position resolution of $\Delta x(\mathrm{rms}) \approx \pm 2\mathrm{mm}$ is representative. Typical mass spectra from data taken during E111 ($\pi^- p$ charge exchange) are shown in Figures 4 and 5.

C. Interface

During the series of experiments (E11, 350, etc.) using the photon detector in the M2 beamline, the detector was interfaced to a Sigma-2 computer. We plan to replace the Sigma-2 with a microprocessor system with video displays. During inter-spill time software on the microprocessor will do source-monitoring and gain-checking, outputing results to both the video displays and the PDP11. During spill time the pulse heights from the photon-detector will read directly into the PDP11 via a DMA interface. The various links are shown schematically below:




Two photon mass distribution at 100 GeV for events from $\pi^- p \to \gamma\gamma n$ taken during Exp 111
π^0
X20
η
X800
η'
15000
10000
5000
0
Events/.01 GeV
0
·5
1·0
Mass $\gamma\gamma$ (GeV)

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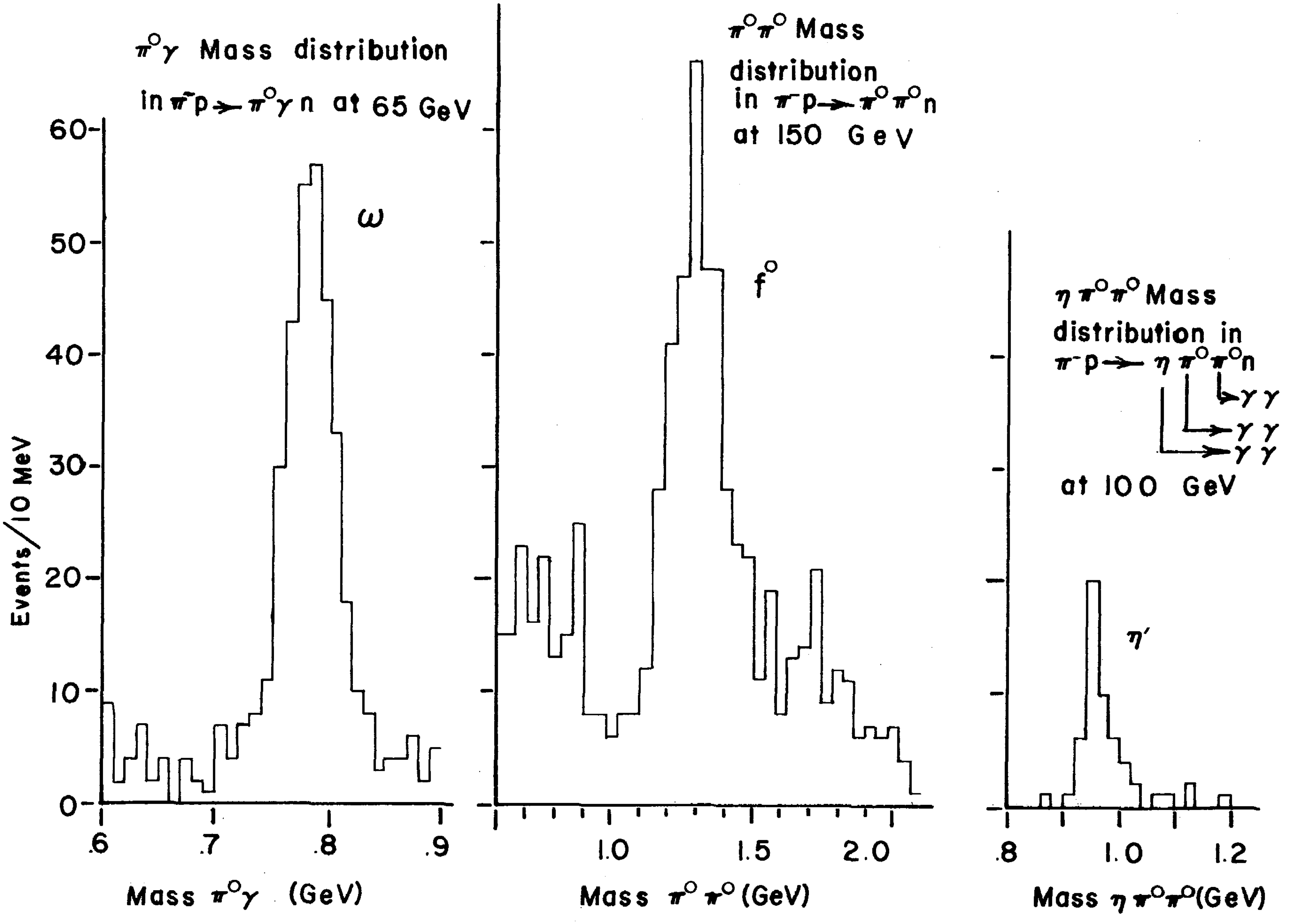

$\pi^0\gamma$ Mass distribution
in $\pi^- p \rightarrow \pi^0 \gamma n$ at 65 GeV
ω
Events/10 MeV
60
50
40
30
20
10
0
.6
.7
.8
.9
Mass $\pi^0\gamma$ (GeV)
$\pi^0\pi^0$ Mass
distribution
in $\pi^- p \rightarrow \pi^0 \pi^0 n$
at 150 GeV
f^0
1.0
1.5
2.0
Mass $\pi^0\pi^0$ (GeV)
$\eta\pi^0\pi^0$ Mass
distribution in
$\pi^- p \rightarrow \eta \pi^0 \pi^0 n$
$\gamma\gamma$
$\gamma\gamma$
$\gamma\gamma$
at 100 GeV
η'
.8
1.0
1.2
Mass $\eta\pi^0\pi^0$ (GeV)

FIGURE 5

IV. Acceptance, Resolution, and Yield Calculations

A. Reactions Yielding $\pi^+\pi^-\pi^o$ Forward in the Final State

The spectrometer as modeled for acceptance calculations is defined in Table V. Two positions were considered for the photon-detector. In position I the photon-detector is placed behind Cerenkov counter C_1. In position II the detector is placed behind Cerenkov counter C_2. The multiple scattering coefficients were obtained from members of Experiment #260 and the resolution of the gamma ray detector from Experiment #111.

The trigger for this experiment would be a requirement of two charged particles through the magnet and an energy requirement in the photon detector. Since the Cerenkov counters will enable us to distinguish between π's and K's, this trigger will include data on $\pi^+\pi^-\pi^o$, $\pi^+\pi^-\eta^o$, $K^{\pm}\pi^{\mp}\pi^o$, $K^+K^-\pi^o$ combinations. The analysis programs for the photon detector enable us to distinguish more than two photons; for example, $f^o \to \pi^o\pi^o \to 4\gamma$. The $(\pi^+\pi^-\pi^o)$ system has resonances at the η(mass = .549 GeV), ω(mass = .783 GeV), ϕ(mass = 1.020 GeV), A_2(mass = 1310 GeV), ω(mass = 1667 GeV), etc. Consequently, we looked at 3 different masses: .78 GeV, 1.2 GeV, and 1.6 GeV. The decays were assumed to be isotropic and the differential cross section from the E111 $\pi^- p \to \omega(\to\pi^o\gamma)n$ preliminary results were used. The shape of the differential cross section for higher mass particles was assumed to be the same as for the omega.

The resulting mass resolution is shown in Table VI. It is seen to be perfectly satisfactory to detect a narrow resonance. To study the acceptance a cut was applied which required that in at least one of the

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Element	Distance from target (meters)	Width (meters)	Height (meters)	Multiple Scattering Coefficient	x Resolution (mm)	y Resolution (mm)	Other Properties
Target	0.			.036			.3 meters long, centered on 0 and of radius .01 meter
Proportional Chambers A	.71	.24	.24	.01	.2	.2	
Proportional Chambers B'	2.93	.72		.0025	.75		no y chamber
Proportional Chambers B	3.25	.84	.36	.005	.75	.75	
Proportional Chambers C	3.83	1.0	.60	.005	.75	.75	
Magnet	4.21						18 kilogauss, 1.02 meter long pole piece
Y-Aperture of Magnet	5.23		.60				
X-Aperture of Magnet	5.99	1.32					
Spark Chambers E	7.05	2.60	1.36		.3	.5	Includes D proportional chamber
Cherenkov Counter C1	12.25			.016			Only multiple scattering from mirrors at downstream end considered
Spark Chambers F	12.50	3.86	1.92		.3	.5	
Gamma Ray Detector	I:13.50 II:24.50	.735	.735				Energy resolution of $\pi^0 = .18\sqrt{E}$(GeV) Position resolution of $\pi^0 = .43$ mm.

Table V : Mass Resolution for $\pi^{\pm}p \rightarrow (\pi^{+}\pi^{-}\pi^{o})X^{\pm}$

Incident Momentum	$\pi^{+}\pi^{-}\pi^{o}$ Effective Mass (GeV)		
	0.77GeV(ω^{o} mass)	1.2 GeV	1.6 GeV
40	11 MeV	17 MeV	19 MeV
100[(a)]	8 MeV	14 MeV	18 MeV
100[(b)]	8 MeV	12 MeV	16 MeV
200	11 MeV	16 MeV	20 MeV

(a) Photon detector located 13.5 m from target.

(b) Photon detector located 24.5 m from target.

two views (x and y planes) of the gamma ray detector the nearest charged particle was no closer than 10 cm to the center of the π^0. This cut is clearly only relevant at the higher energies where the charged particles are bent less by the magnet. It was also required that the center of the π^0 be no closer than 3 cm to the edge of the detector. The resulting acceptances are shown in Table VII. From the E111 results we obtain a total ω^0 cross-section of 3.5 μb at 40 GeV, 1 μb at 100 GeV, and .3μb at 200 GeV. Allowing for the branching ratio of 0.9 and for a cos θ cut on the π^0 decay at 0.8 we estimate that in 100 hours one can see 45,000 omegas at 40 GeV, 12,000 omegas in position I at 100 GeV or 15,000 omegas in position II at 100 GeV, and 4,000 omegas in position II at 200 GeV. For the higher mass particles, it is harder to make estimates; thus at 6.95 GeV/c, Matthews et al.[9] find for $\pi^+\pi^-\pi^0$ decay:

$$\sigma(\pi^+ n \rightarrow \omega^0 p) = 80\ \mu b$$

$$\sigma(\pi^+ n \rightarrow A_2^0 p) = 54\ \mu b$$

$$\sigma(\pi^+ n \rightarrow \omega(1680) p) = 34\ \mu b.$$

Unfortunately Fox and Hey[10] claim you cannot scale these numbers to higher energy as the A_2^0 and $\omega(1680)$ have a much larger B exchange contribution than ρ at low energies compared to the ω. Therefore as B exchange falls faster with energy than ρ, the high energy A_2 and $\omega(1680)$ cross-sections will be lower than the above ratios suggest. One may guess that our yield of these high mass resonances will be between 10 and 25% of the $\omega(783)$.

As mentioned above another decay observed simultaneously is the $\eta \rightarrow \pi^+\pi^-\pi^0$. The physics here is of lesser interest because the reaction $\pi^- p \rightarrow (\eta \rightarrow \gamma\gamma) n$ has been studied by E111 and because the η is spinless. The geometrical acceptance is high and its cross-section is similar to

Table VI: Detection Efficiency for $\pi^{\pm}p \rightarrow (\pi^{+}\pi^{-}\pi^{o})X^{\pm}$

Incident Momentum	$\pi^{+}\pi^{-}\pi^{o}$ Effective Mass (GeV)		
	0.77 GeV (ω^{o} mass)	1.2 GeV	1.6 GeV
40 GeV$^{(a)}$	0.75	0.34	0.12
100 GeV$^{(a)}$	0.70	0.70	0.69
100 GeV$^{(b)}$	0.91	0.64	0.46
200 GeV$^{(b)}$	0.81	0.77	0.75

(a) Photon detector located 13.5 m from target.

(b) Photon detector located 24.5 m from target.

Assumptions:

1. Istropic distribution in the $\pi^{+}\pi^{-}\pi^{o}$ rest frame
2. Spatial separation at the detector between the π^{o} and charged $\pi \geq 10$ cm in at least one view.

that of the ω^o. However its branching ratio to $\pi^+\pi^-\pi^o$ will reduce its signal to about one-quarter of that of the omega.

Also, the η'(mass = .958 GeV) will be observed via its $\eta^o\pi^+\pi^-$ and $\rho^o\gamma$ decays and so over half the η''s produced should be observed. Our event yield for $\eta' \rightarrow \pi^+\pi^-(\eta,\gamma)$ is about a quarter of those quoted for the earlier.

V. Run Plan

We propose to carry this experiment in three stages.

Stage I

The photon detector will be installed at the far downstream end of the spectrometer. It will be tested parasitically during the Autumn 1977 E110 data run and will be used to measure but not to trigger on neutrals. Power supplies for the photon detector phototubes will be installed in the pit area of the MPS Wonder Building. The Caltech ADC's used for E111 will also be used for this experiment so there will be no additional request for equipment from PREP. The photon detector will be monitored by a self-contained microprocessor system (see page 17) with video displays. This controller with its associated electronics will exist in 2-3 racks which will be installed in the current MPS control room. During spills data from the photon detector will be written on E110 data tapes and used by the current MPS collaboration in its analysis. Table VII shows how the photon detector will be used to enhance the physics of reactions studied in E110.

We wish to emphasize that the parasitic activity for the fall, 1977 run does not require any additional requests from Fermilab since:

a. the Caltech ADC's will be used;

b. the interfaces to and from the photon detector, microprocessor, and PDP11 could be built this summer;

c. the photon detector will not be used in the trigger.

Furthermore, this parasitic activity will not degrade from E110 running since:

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TABLE VII

Reactions to be studied in Autumn 1977 E110 Run with Photon Detector used to measure but not to trigger on Neutrals.

FINAL STATE	REPRESENTATIVE PHYSICS
$\pi^+\pi^-\pi^-\pi^o$ Semi-inclusive	Production dynamics of $B^- \to \pi^-\omega^o$. Spectroscopy of $\pi\omega$, $\pi\eta$ resonances
$\pi^+\pi^-\pi^o$ Exclusive	Production dynamics and spectroscopy of 3π resonances in non-diffractive mode
$\bar{K}^oK^-\pi^o$ Semi-inclusive	Diffractive (K^- beam) and non-diffractive (π^- beam) studies of $K\bar{K}^*$ resonances
$\bar{K}^o\pi^+\pi^-\pi^o$ Semi-inclusive	$\bar{K}\pi$, $\bar{K}\pi\pi$ spectroscopy in all charge modes
$K^o\bar{K}^o\pi^o$ Semi-inclusive	$K\bar{K}^*$ spectroscopy

NOTES:

a) In addition to π^o we will also see η^o, $\pi^o\pi^o$ states.

b) Semi-inclusive means any number of particles allowed in the target house with the indicated topology seen in the forward spectrometer.

c) Exclusive means no particles seen in target house (i.e., neutron recoil).

d) Compared with E110, the addition of π^o detector channels allows $\pi\omega$, $\pi\eta$, $\pi^+\pi^-\pi^o$ and $K\bar{K}^*$ as new channels with $\bar{K}\pi$, $\bar{K}\pi\pi$ studied in all charge states.

a. additional physicists not associated with E110 will participate in the installation and checkout of the detector;

b. the microprocessor system will be used to monitor the performance of the photon detector. There will be no additional software to add the new ADC's to the data already being read in;

c. the placement of the detector will be such as to not interfere with the original physics of E110.

Stages II and III

These stages call for running immediately after (Stage II) the E110 run and after the proposed upcoming Meson Lab Shutdown (Stage III). The E110 trigger studies show that we can run E110 with about 10^6 beam per 2 second spill. We will not have the firm numbers until the Autumn run but we believe the trigger rates will drop substantially when we also require that ≥15% of beam energy appear in the π^o detector. This is not just because we are triggering on a smaller sample of interactions but also many sources of background triggers (e.g., beam plus delta rays in $\pi^+\pi^-(\pi^o)$ topology) are eliminated.

Table VIII shows the triggers we currently plan for Stages II and III. Of course, our plans might well be changed as the results from the first E110 runs are available. Note the important $\pi^+\pi^-\pi^o$ final state is improved over the parasitic E110 Autumn run by both higher beam and removal of the exclusive requirement: this should allow an order of magnitude higher yield.

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TABLE VIII

Reactions to be studied when π^o detector used in trigger.

E110 TOPOLOGIES

Final States	Comments
$\pi^+\pi^-\pi^-\pi^o$ $\bar{K}^oK^-\pi^o$ $\bar{K}^o\pi^+\pi^-\pi^o$ $K^o\bar{K}^o\pi^o$ Semi-inclusive	Same as Table VII but higher beam intensity.
$\pi^+\pi^-\pi^o$ Semi-inclusive	Remove Exclusive requirement as trigger rate reduced. Thus allowed much better spectroscopy studies of 3π resonances.

NEW TOPOLOGIES

Reactions	Comments
$\bar{K}^o\ \pi^o$ Semi-inclusive	Clean trigger (cf. $K^o\bar{K}^o$ discussion in c) for $K\pi$ spectroscopy.
$\pi^o n$ Exclusive	Measurement of $\pi^-p \rightarrow \pi^o n$ to compare with E111, (and so provide check of veto house performance) and extended to higher energies

Stage II Request

1. We are requesting a data run for P523 immediately after the fall E110 run in which the photon detector would be used in the trigger.
2. Beam: Negative 200 GeV/c beam with intensity of 3.0×10^6 particles/2 sec.
3. Hours: 400 hours.
4. Typical Yields (number of events):
   a. Specific Reaction: $\pi^- p \to \omega^o n$: 24,000 events
   b. Spectroscopy: For a resonance produced with $\sigma = 1\mu b$ and a detection efficiency of 20%: 15,000 events.

Stage III

This would take place after the Meson Lab shutdown. We would request another 400 hours of running at 300 GeV/c incident beam momentum if the M6W beamline is upgraded with superconducting magnets or at 100 GeV/c if the beamline is not upgraded.

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